SPATIO-TEMPORAL CORRELATION OF CLIMATE INDICES AND RIVER FLOODS IN NORTHWESTERN ITALY

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KEY POINTS

- *Describing the annual flood peaks with climate change indices (ETCCDI)*
- *Preliminary analysis on the differences in the floods magnitude tendency based on the geographical location*
- *Analysing the climate drivers of flood temporal variability*

1 INTRODUCTION

Floods are hydrological events potentially causing severe damages to population living nearby the rivers. In the Alpine region, the occurrence of floods is strongly related to specific climatic conditions that have changed during the last decades and will change in the future, due to climate change. Although the impact of precipitation and temperature patterns on river flows is a well discussed topic in hydrology, few studies have focused on the relationship between river flood discharges and the standard climate change indices, as defined by the Commission for Climatology/World Climate Research Programme/Technical Commission for Oceanography and Marine Meteorology (CCI/WCRP/JCOMM) Expert Team on Climate Change Detection Indices (ETCCDI). The description of how these indices are calculated is available at: *https://www.climdex.org/*. This study correlates annual maximum discharge time series with annual series of ETCCDI indices at the catchment scale, in Northwestern Italy. The aim is to determine which indices better describe annual floods and to analyse the possible climate drivers of flood temporal variability.

2 DATA AND METHODS

Mean daily discharge data from stream gauges, covering approximately the period from 2000 to 2019, are used to extract annual maxima for 95 catchments (Fig. 1). A gridded dataset (resolution 0.125x0.125°) of observed daily precipitation and daily minimum and maximum temperature (Optimal Interpolation Dataset, Arpa Piemonte), derived from a dense network of rain gauges, is used for the calculation of ETCCDI indices, by considering the hydrological year (1st October – 30th September).

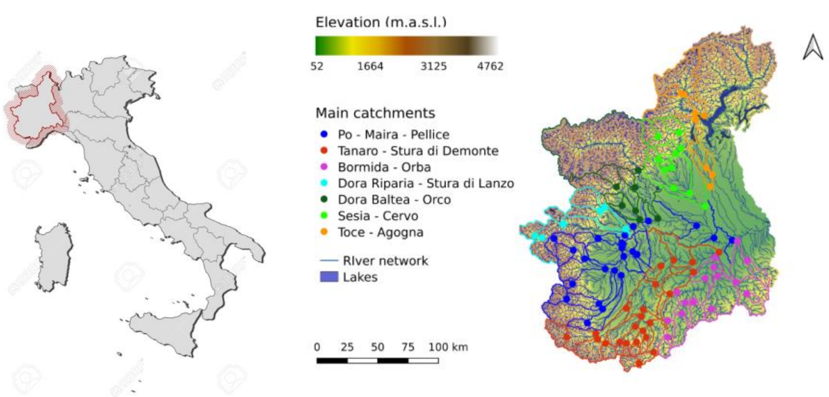

Figure 1: Geographical position of the study area to the left and elevation map with location of stream gauges, coloured by main rivers, to the right.

First, Spearman's rank correlation was calculated for annual maximum discharges and climate indices time series, to test the hypothesis that maximum discharges are significantly correlated to one or more of these indices. The significance of the correlation was tested with one-side Student's t-test at 5% significance level. The Spearman's correlation coefficient is chosen as statistical measure due to the non-linear relationship between precipitation, temperature and discharge. Then, a trend analysis of the time series was performed by calculating a linear trend using the Theil-Sen's slope estimator, as described in Sen (1968) and Theil (1950). The trends were tested for significance using one-side Mann-Kendall test at 5% significance level (Mann, 1945). Finally, trends of maximum discharges and trends of climate indices were correlated, by means of the Spearman's rank correlation, to get information about which indices better explain the temporal variability of floods.

3 RESULTS AND DISCUSSION

The results in terms of Spearman's correlation coefficient among maximum discharges and climate indices show that the maximum 1 day precipitation (Rx1day), the maximum consecutive 5-day precipitation (Rx5day), the annual total precipitation when daily precipitation is above the 95th percentile (R95p) and the annual total precipitation when daily precipitation is above the 99th percentile (R99p) are strongly positively correlated to discharge maxima over the entire study area, and the results are field significant (Fig. 2).

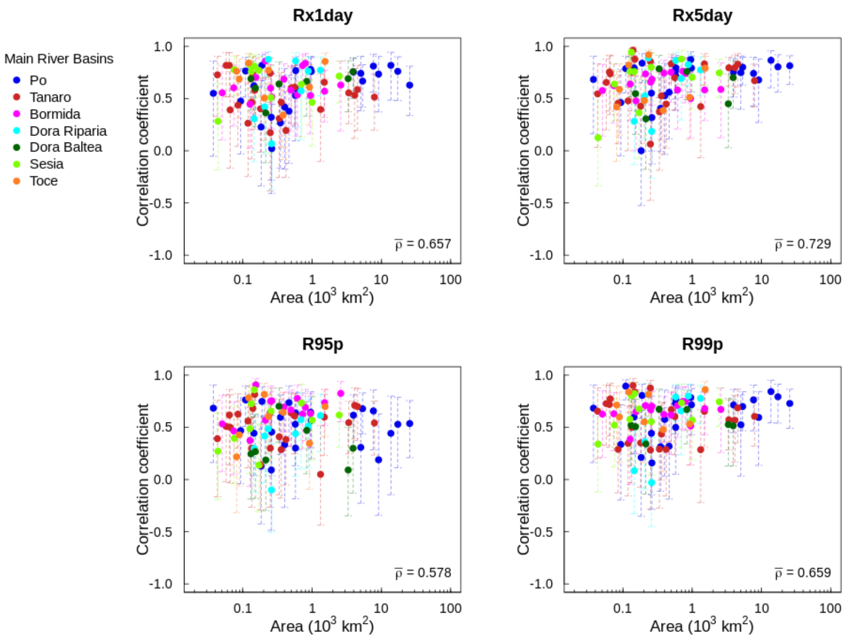

Figure 2: Scatterplots of the Spearman's rank correlation coefficients among annual maximum mean daily discharges and the maximum 1 day precipitation (Rx1day), maximum 5-day precipitation (Rx5day), annual total precipitation above the 95th percentile (R95p) and annual total precipitation above the 99th percentile (R99p) vs. catchment area, coloured as in Figure 1. Mean values of correlation coefficients, weighted for the uncertainty, are reported.

It's worth noting that R99p correlates better than R95p as it is a very good proxy for the annual maximum rainfall event, while R95p could be more useful to describe other indices of extreme discharge (e.g., a flow volume threshold). Moreover, the Rx5day correlates better in large catchments while Rx1day is more suitable for very small catchments. This is related to the interplay between the duration of rainfall events and the catchment response time: longer (shorter) precipitation events are relevant in determining floods in larger (smaller) catchments. These results also suggest that some ad-hoc indices (e.g., Rx3day) could be used to describe floods occurring in medium-size catchments, which show, on average, lower correlation coefficients.

The trend analysis reveals that floods don't show a clear tendency and less than 10% of the catchments have a significant trend according to Mann-Kendall test, but this is probably influenced by the quite limited length of the series. However, some spatial coherence can be observed (Fig. 3). Increasing trends seem to prevail in Bormida and Tanaro catchments (southern area). For the Po river, the tendency is negative for small catchments, typically located in the western Alps, and positive for medium-size catchments, while for large valley catchments no distinct pattern is visible.

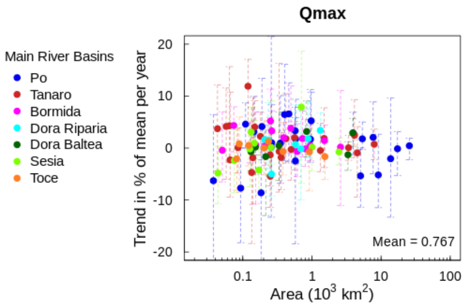

Figure 3: Scatterplot of trends of annual maximum mean daily discharges (Qmax) vs. catchment area, coloured as in Figure 1. Mean value of trends, weighted for the uncertainty, is reported.

Despite the presence of some noise, the correlation between trends of maximum discharge and trends of climate indices provides some interesting information. In fact, the total annual precipitation (PRCPTOT) shows the highest significant correlation, with a Spearman's correlation coefficient of 0.5, followed by the maximum consecutive 1-day precipitation (Rx1day) and the annual total precipitation when daily precipitation is above the 99th percentile, whose tendency is positively correlated with the tendency of maximum discharges (Fig. 4). This is an indication that, differently from what obtained at the annual timescale, the long-term variability of floods seems to be better explained by the tendency of mean precipitation, which is responsible for catchment saturation, rather than extremes of the precipitation distribution. Looking at temperature, trends of growing season length (GSL) appear to have a positive correlation with trends of maximum discharges, while trends of the maximum value of daily maximum temperature (TXx) and trends of the maximum value of daily minimum temperature (TNx) are negatively correlated. However, the result for GSL is likely to be a spurious correlation, given that in most of the catchments the trends are null and their spatial variability is very limited. Looking at the elevation classes for TXx and TNx, the correlation seems to be mainly driven by high elevation catchments, with smaller spatial variability in the lowlands. This can be explained by the fact that the considered variables are summer temperatures that can impact both the snow and ice melting processes in high elevation catchments. An increasing trend of daily temperature is likely to be responsible for an increasing depletion of compacted snow and ice. As a result, the contribution to late spring-summer runoff events and/or the probability of rain-on-snow events in the Alpine catchments becomes lower, leading to decreasing maximum flows.

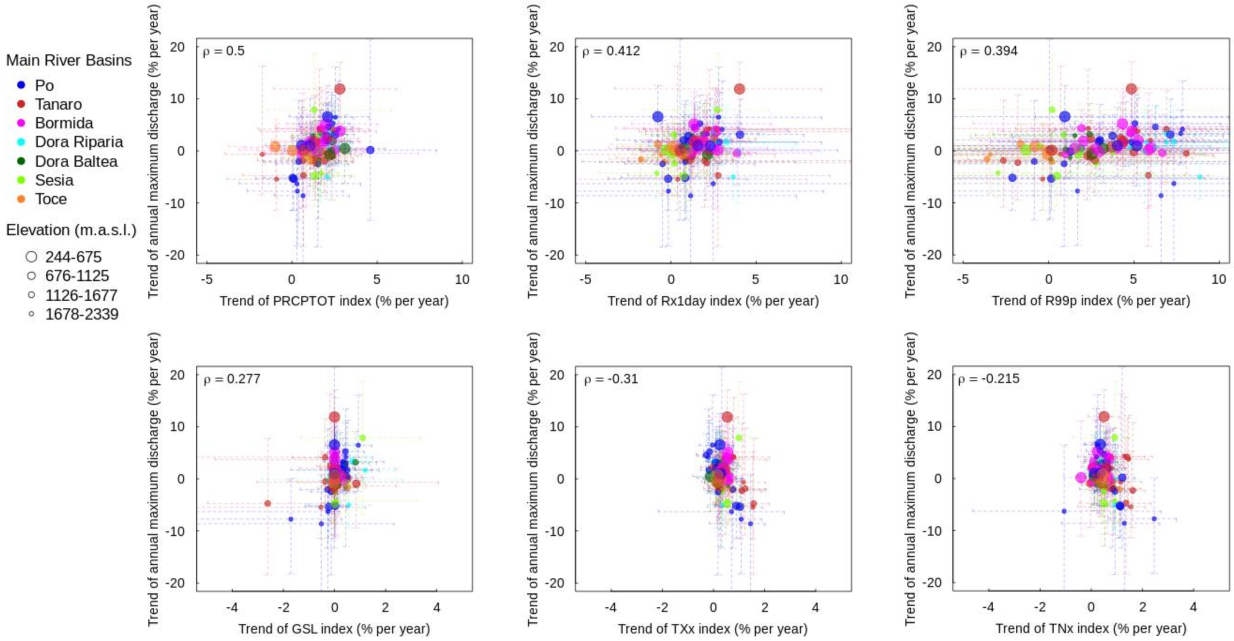

Figure 4: Scatterplots of trends of annual maximum mean daily discharges vs. trends of annual total precipitation (PRCPTOT), maximum 1-day precipitation (Rx1day), annual total precipitation above the 99th percentile (R99p), growing season length (GSL), maximum value of daily maximum temperature (TXx), maximum value of daily minimum temperature (TNx), discretized by catchment mean elevation, coloured as in Figure 1. Spearman's rank correlation coefficients are reported.

4 CONCLUSIONS

Despite the limitations given by the small spatial variability of trends of annual maximum discharges and ETCCDI indices, the results show that, differently from the year-to-year correlation, interannual changes of extreme discharges can be better explained by the interannual changes of the total annual precipitation. This suggests that future projections of the annual precipitation, available from climate models, can be used as covariates for non-stationary flood frequency analysis.

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